

PERFORMANCE ANALYSIS OF IMPROVED AUTONOMOUS POWER CONTROL MAC PROTOCOL (IAPCMP) FOR MANET'S

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ABSTRACT

Power Control in Mobile Ad Hoc networks is a critical issue, since nodes are powered by batteries. The main idea of power control schemes is to use different power levels for RTS/CTS and DATA/ACK. These schemes may degrade network throughput and reduce energy efficiency of the network. In this paper we have evaluated the performance of Improved Autonomous Power Control MAC Protocol (IAPCMP), that allows nodes to dynamically adjust power levels for transmission of DATA/ACK according to the distance between the transmitter and its neighbors. In IAPCMP power level for transmission of RTS/CTS is also adjustable. This also used maximum power level for transmitting DATA/ACK periodically to make neighboring nodes aware about ongoing transmission. The performance of IAPCMP is evaluated through the metrics namely, packet delivery ratio and rate of energy efficiency. The simulation results show significant improvement in protocol.

KEYWORDS

IEEE 802.11, Power Control, Energy Saving, Medium Access Control, Ad Hoc Network

1. INTRODUCTION

Mobile Ad Hoc Networks are multi-hop in nature and nodes are operated in distributed manner without any centralized infrastructure. The topology of the network is dynamically changes due to the nodes mobility. The nodes may join and leave the network frequently. The interests in such networks are from their ability to provide temporary and instant wireless networking solutions, where cellular infrastructures are not easily possible to establish [1, 13, 15].

The Authors [2, 3, 6, 10] have given various power control schemes, out of these some are discussed here. In these schemes the power saving can be done in various ways. One way is to make use of some power saving mechanism, which let a node stay in a sleep state by powering off its wireless network interface, when no communication is required. Another alternative way is to use power control mechanism, which can adjust transmitting power level to save energy.

In [4,14], Authors are interested in controlling transmit power level to reduce energy consumption and to increase end-to-end delivery. It should be noted that in Mobile Ad Hoc Networks transmitting power level control is important for two reasons. One reason is it affects the traffic carrying capacity. And other is it also affects the spatial reuse i.e. simultaneous transmission. Since Mobile Ad Hoc Networks are dynamic in nature, therefore, to design an

efficient power control protocol for MAC is a challenging task. Various energy efficient MAC schemes have been proposed for power control in the literature. However, very few schemes conserve energy without degrading the performance of the networks. But most of the schemes conserve energy by degrading throughput, delay or other metrics [11, 12].

We define some terms to make clear understanding on the protocol. So, here given the basic definitions of transmission range, carrier sensing range, and carrier sensing zone [16,17].

Transmission Range– Nodes in transmission range are able to decode data packets correctly. When two nodes transmit simultaneously, there are RTS/DATA transmission range of the sender and CTS/ACK transmission range of the receivers.

Carrier Sensing Range– Nodes in a carrier sensing range can sense the sender’s transmission. This is usually larger than the transmission range. It is generally two times larger than the transmission range.

Carrier Sensing Zone – The area in which nodes can sense the incoming signals but cannot decode it correctly, is called carrier sensing zone.

In MAC protocols collision may occurs, to explain collision we explain the term hidden terminal and collision area as follows.

Collision Area- It is area in which hidden terminals are present. In the collision area, nodes are neither in RTS/CTS transmission range, nor in DATA/ACK transmission range. But these may inside the carrier sensing zone of the RTS or CTS. These may at beginning know the ongoing transmission, but lose sense later. Some nodes in the collision areas may sense the transmission for a while but they lost it eventually because of the power decrease (as happen in BASIC) or because of the asymmetry of the link. As shown in figure 1. The shadow parts in figure 1 denote the collision area, which are called left and right collision area. The transmitting nodes (such as a node A) in the left collision area will possibly affect the DATA reception in node D, while the node (as node F) in the right collision area may interfere with the ACK received by node C.

Hidden Terminal- A node is in the receiver’s carrier sensing zone, but is not in sender’s carrier sensing zone or transmission range, and it may cause a collision to the reception of a DATA packet at the receiver. As shown in figure 1, node F is the hidden terminal when node C transmits RTS to node D. similarly, node A is the hidden terminal when node D transmits CTS to node C.

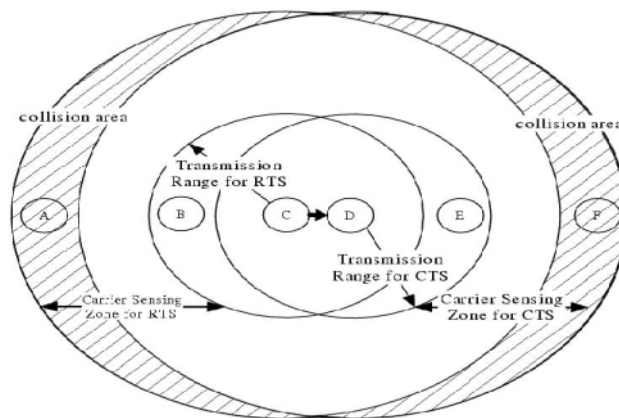


Figure 1 Hidden Terminal and Collision Area [17]

In this paper we have evaluated the performances of Improved Autonomous Power Control MAC Protocol (IAPCMP) that enhance energy efficiency and also improve the end-to-end delay. The rest of this paper is organized as follows. Section 2 presents the work related to the area. Section 3 deals a brief introduction of IAPCMP and its analysis with the other metrics. In section 4, we discussed simulation and performance analysis of IAPCMP. Section 5 concludes the works and gave the possible future extension.

2. RELATED WORK

The IEEE 802.11 standards proposed for wireless LANs have been widely applied to ad hoc wireless networks. The IEEE 802.11 specifies the parameters for both physical (PHY) and medium access control (MAC) layer of a network. The MAC layer is the host for a set of protocols, which are responsible for regulating the use of a shared medium. IEEE 802.11 is the mostly used MAC protocol [5,7].

2.1. IEEE 802.11 MAC Protocol

IEEE 802.11 MAC protocol is a widely adopted one, in which the header of RTS (Request to Send), CTS (Clear to Send), and DATA include time duration to indicate when ACK can be received, that is, if a node can decode RTS, CTS or DATA correctly, it will know the on-going transmission and can avoid collision at the very first stage. In this scheme, RTS/CTS are sent by using maximum transmit power level, and DATA/ACK are also sent by maximum transmit power level as specified in CTS, RTS respectively. Since here we use same power level for RTS/CTS and DATA/ACK transmission, so it consumes more energy and also reduces the spatial reuse [6, 8].

2.2. The BASIC Power Control MAC Protocol

The Basic Power Control MAC protocol uses different transmitting power levels in the handshake RTS/CTS frames and DATA/ACK frames [4, 6]. When a node transmits the RTS/CTS, maximum power is used to make all other nodes know the ongoing transmission; while a node transmits

DATA/ACK lower power should be used. Let $P_{desired}$ be the power level for transmitting DATA/ACK, and is given by

$$P_{desired} = \frac{P_{max}}{p_r} * R_{xthresh} * \beta \quad (1)$$

Where $R_{xthresh}$ is the minimum signal strength necessary to receive the signal, which is determined by the physical characteristics of the node, and β is a constant. This protocol may introduce more collisions. The more collisions means more retransmission, and then higher throughput will be achieved by higher energy consumption. This scheme will not be beneficial for us because we are interested in finding higher throughput in less energy consumption. However, if mobility is present, the low power level transmission will also cause more retransmission, and thus it will consume higher energy.

2.3. Autonomous Power Control MAC Protocol

This protocol can adjust the transmitting power level for DATA/ACK and RTS/CTS packets both with respect to the current network situation [6]. This process of adjusting transmitting power

level may result in different power levels used by different transmitters in the network. This may cause excessive collision, and it is likely to impossible to calculate the optimal transmitting power level according to the global network condition dynamically. A wireless channel uses shared medium. Therefore excessive high power level causes interference. This reduces traffic carrying capacity, and battery life of the network. However, if the mobility is present this protocol degrades the network efficiency.

2.4. Improved Autonomous Power Control MAC Protocol

This protocol can adjust the transmitting power level for RTS/CTS and DATA/ACK packets as done by Autonomous Power Control MAC protocol. Here Author [6,18], uses maximum power level p_{\max} for data transmission periodically instead of $p_{\frac{data}{ack}}$ when first data collision occurs.

The performance of this protocol evaluated in terms of throughput in mobile and static scenario. Therefore, throughput is not sufficient to evaluate the performance of any protocol. So, we have extends our evaluation of this protocol in terms of end-to-end delay and energy consumption.

3. PERFORMANCE ANALYSIS OF IAPCMP

In this section, we discuss the Improved APCMP for MANETs [18]. This protocol (IAMPCP) is considered as improved version of Autonomous power control MAC protocol [6].

In this work we perform the network analysis of IAPCMP in terms of delay ratio and rate of energy efficiency. More the rate of energy efficiency means the protocol is more efficient. The IAPCM protocol can adjust the transmitting power level for DATA/ACK packets as well as RTS/CTS packets according to the network situation in order to reduce the energy consumption. In IAPCMP transmitting power level for a local node group is adjusted in two ways. The first is to follow an appropriate power level for transmitting DATA/ACK, depending on the average distance from the transmitter to all current neighbors. The other is to adjust the power level for transmitting next RTS/CTS to a value proportional to the DATA/ACK power level. Therefore, the energy consumption can be lowered by collision avoidance.

In a MAC protocol, we know that the distance can be estimated by using the transmitting power level at a transmitter and the actual received signal power level at a receiver. Therefore, a bidirectional links between transmitter and receiver can be ensured, as long as the transmitter/receiver transmits packets using some suitable power level, at which the receiver/transmitter can receive the same signal power level. Using this estimated distance information, the required power level can be calculated. Based on this consideration, in IAPCMP, transmitting power for sending RTS/CTS packets is adjusted to a level just slightly higher than that is required for transmitting DATA/ACK packets. We also increase the transmitting power level for transmitting DATA/ACK periodically to overcome the hidden terminal problem. The time period to increase the transmit power is considered less than the SIFS time. Further, to ensure connectivity of the network, we increase transmitting power level gradually, if it is too low to reach any other node n the network.

3.1. Calculating for Transmitting Power Level in IAPCMP

In this protocol we give the process by which the transmission power can be calculated which is similar to the authors [6] idea. The only difference in my calculation is that we are taking $k = 4$. In this the distance information is used to determine the transmitting power level. It is also

assumed that the noise level at a receiver is less than the signal level. The signal attenuation is given by

$$d = \sqrt[4]{\frac{p_{rts/cts}}{p_{rec}}} * \varepsilon \quad (2)$$

Where, $p_{rts/cts}$ is transmitting power level for RTS/CTS packets, p_{rec} is the received signal power level, and ε is a constant dependent on the antenna gain, system loss and wavelength. Here we set it to 1.

For a given transmitter, suppose that there are $(k - 1)$ mobile nodes as its neighboring nodes. Let us consider a transmitter wants to send a data packet to another mobile node, say k^{th} node. It firstly calculates the distance from the transmitter to the k^{th} node. The average estimated distance from the transmitter to the k^{th} mobile nodes, is given by

$$d' = \frac{1}{k} \sum_{i=1}^k d_i \quad (3)$$

Where d_i is the estimated distance from the transmitter to the i^{th} neighboring node.

The power level for transmitting DATA/ACK packets from transmitter to the k^{th} node is given by

$$p_{\frac{data}{ack}} = d'^4 * R_{xthresh} \quad (4)$$

The estimated distance between transmitter and the k^{th} node is represented by d_k , and d' is the average of estimated distance of all k neighboring nodes. If $d_k > d'$, transmitted via its neighbors which transmitter cancels the transmission due to insufficient transmission power level. The data packet has to be transmitted via its neighbors which are close to it.

The transmitting power level for the next RTS/CTS is calculated as follows

$$p'_{\frac{rts}{cts}} = p_{\frac{data}{ack}} * \beta \quad (5)$$

Where β is a parameter related to the network situation and here it is $\beta > 1$.

3.2. Transmission cycle for packets in IAPCMP

The transmission cycle of IAPCMP consists of five steps, which are as follows [18]:

Firstly, a transmitter sets the value of $p_{\frac{rts}{cts}}(p_{rtsT})$ and p_{ackR} , which is stored in the routing table and in the RTS packet. Then the transmitter sends RTS packet using power level $p_{\frac{rts}{cts}}$.

The receiver receives RTS packet by power level p_{rec} and obtains the information about p_{rts} , p_{ackR} . With this information, it calculate the desired power level for DATA packets transmission as follows

$$p_{dataT} = \frac{p_{rtsT}}{p_{rec}} * R_{xthresh} \quad (6)$$

The receiver estimates distance from the current transmitter by using p_{ackR} with the estimated distance, New power level p_{data} and p_{rts} for the receiver is calculated from the equation 4 and

5. The new value of p_{rts} is set as the new RTS/CTS for receiver. The receiver sends the values of p_{rts} (p_{ctsR}) and p_{dataT} in the CTS packet to the transmitter with the new power level p_{rts} .

Transmitting node receives the CTS packet by p_{rec} and obtains the information carried by it. Using this information the desirable power level p_{ackR} for the receiver to transmit ACK packet is given by

$$p_{ackR} = \frac{p_{ctsR}}{p_{rec}} * R_{xthresh} \quad (7)$$

Then, transmitter calculates and saves the estimated distance to the current receiver d_r . The average distance d' to all the neighbors is calculated. Then it can calculate- p_{data} , p_{rts} , and p_{rts} as new transmission power for RTS/CTS. For data transmission it use p_{data} .

If the transmitting node does not receive CTS packet after a timeout, it increases the power level for transmitting RTS/CTS to the previous used value and send RTS again.

We use the maximum power level p_{max} for data transmission periodically instead of p_{data} whenever first data collision occurs. The time for periodically use of p_{max} is set to less than SIFS. After receiving the DATA packet, receiver send back ACK packet using the power level p_{data} . If the transmitter receives ACK before the timeout, transmission cycle is completed successfully. Otherwise, the transmitter transmits the DATA packet again in a same way up to the maximum retransmission limit.

4. PERFORMANCE EVALUATION

In this section, we evaluated the performance of the IAPCMP [18] with network simulator GloMoSim [9] and compared with other power control MAC protocols.

4.1. Simulation Environment

We have considered varying node density i.e. 4, 8, 12, and 16 with and without mobility. Further the other parameters used in simulation are listed in table 1. The career sensing range is 550 m. and the highest power level at 24.5 dBm.

Table 1. Simulator Parameters

Simulation Time	1000 second
Network Area	500 x500
Radio Transmission Range	250 m
Propagation model	two-ray path loss
Bandwidth	2 Mbps
Node Placement	Random
Mobility-Wp-pause	0.1 Millisecond
Mobility-Wp-Min-Speed	0 m/s
Mobility-Wp-Max-Speed	10 m/s
Noise Figure	4
Radio-Tx-Power	24.5 dBm
Radio-Antenna-Gain	0.0 dBm
Radio-Rx-Sensitivity	-71.42 dBm
Mobility Model	Random Way Point
Routing	LAR1
Promiscuous-Mode	No

4.2. Simulation Results

We used following metrics to evaluate the performance of the IAPCMP, APCMP, BPCMP, and IEEE 802.11 protocols under both the mobile and static environment. In mobile condition the maximum speed is considered 10 m/s.

Delivery Ratio: It is the total number of data packets successfully delivered out of the total number of data packets sent. This shows an external measure of connectivity performance.

$$\text{Delivery Ratio} = \text{Total number of packets deliver} / \text{Total number of packets sent}$$

Rate of Energy Efficiency: It is the number of data bits delivered/joule energy consumed. Higher the rate of energy efficiency means protocol more efficient.

$$\text{Rate of Energy Efficiency} = \text{total number of data bits} / \text{total energy consumed (joule)}$$

Figure 2 shows the delivery ratio for different network size of 4, 8, 12, and 16 nodes in a static situation. Therefore, from results we conclude that the delivery ratio of IAPCMP is comparatively better than other protocols i.e. BPCMP, APCMP, etc.

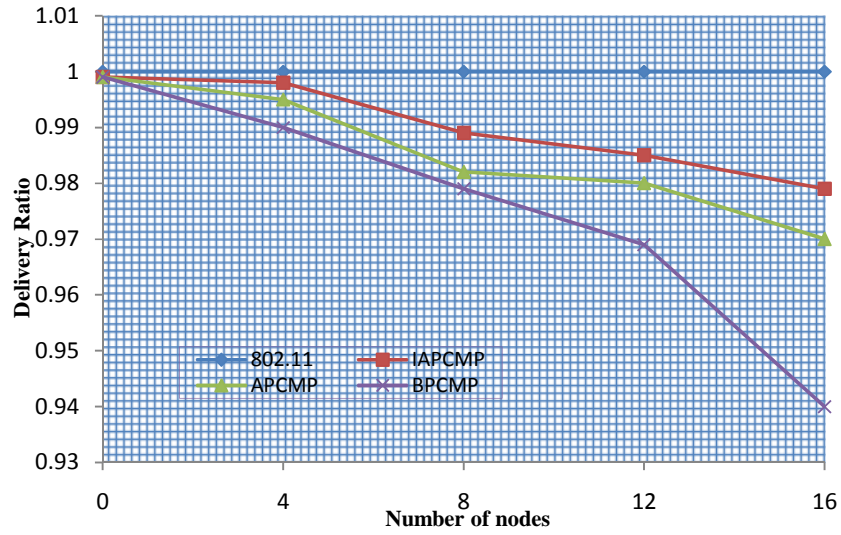


Figure 2. Comparison of Delivery Ratio in Static Situation

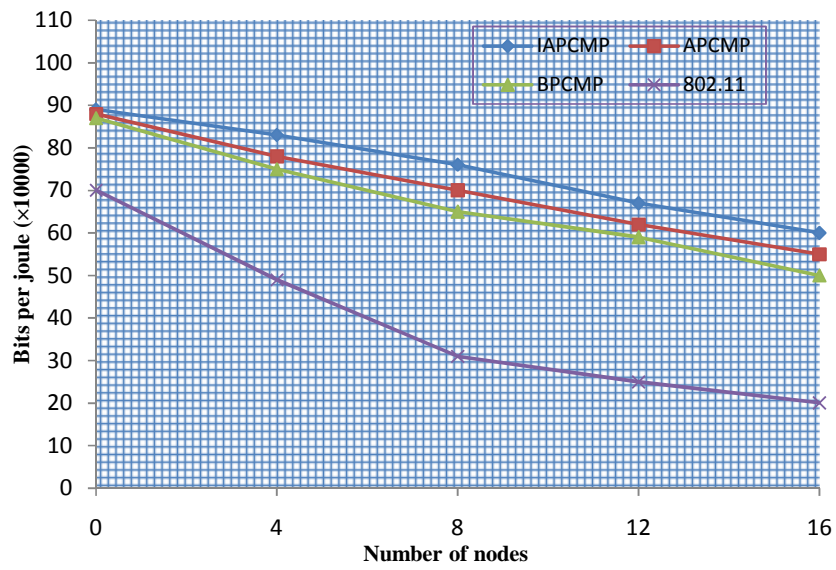


Figure 3. Comparison of Energy Efficiency in Static Situation

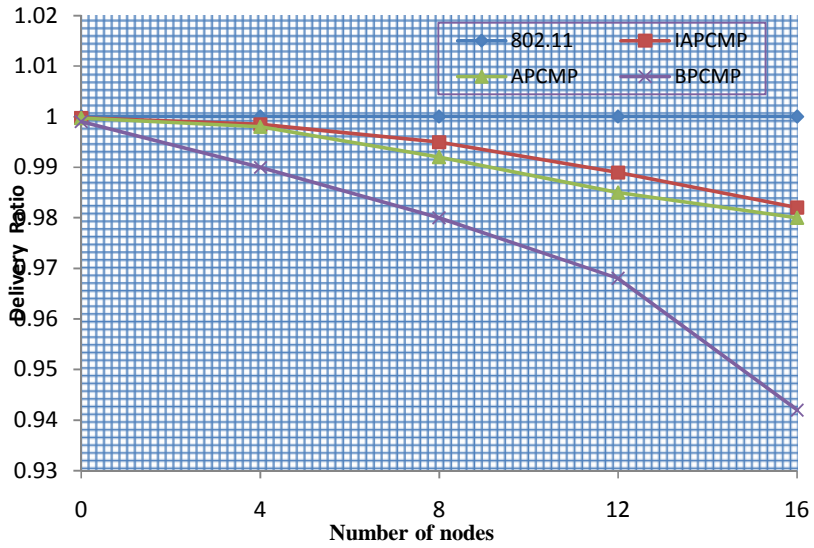


Figure 4. Comparison of Delivery Ratio in Mobile Condition(max speed 10 m/s)

Figure 3 shows the rate of energy efficiency for different network size of 4, 8, 12, 16 nodes in static situation. Therefore, from the figure 3 it is clear that IMPCMP is more energy efficient than the BPCMP, APCMP, IEEE 802.11.

Figure 4 shows the delivery ratio of network in mobile environment with maximum moving speed of a node is 10 m/s. Figure 4 tells that the IAPCMP performs better than BPCMP, and other protocols.

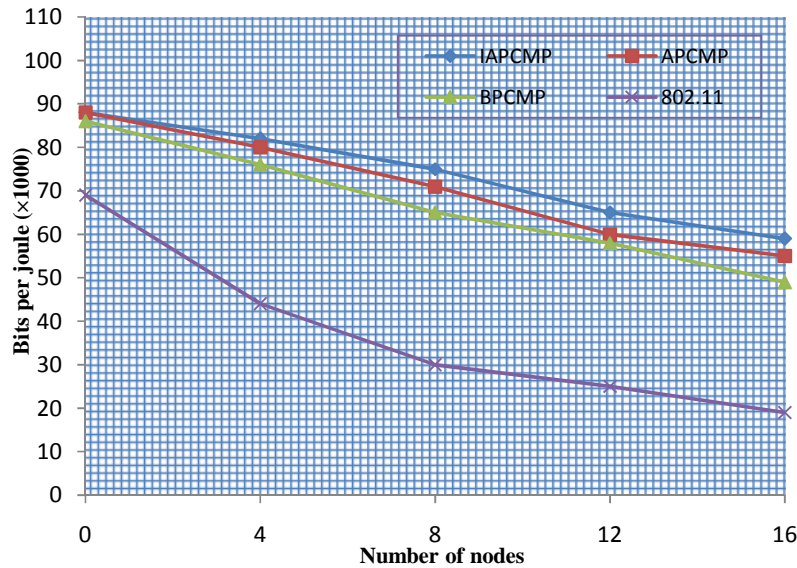


Figure 5.Comparison of Energy Efficiency in Mobile Condition (max speed 10 m/s)

Figure 5 clearly shows that energy efficiency of proposed protocol in mobile situation with maximum moving speed of node (10 m/s) is better in comparison to APCMP, BPCMP, IEEE 802.11.

5. CONCLUSIONS

Mobile Ad Hoc Networks are powered by batteries and there is no centralized administration. Therefore, to reduce overall energy consumption is vital for providing quality of service in mobile ad hoc networks. Thus, to increase the network performance, improved autonomous power control MAC protocol for mobile ad hoc networks can adjust transmitting power level automatically as well as periodically according to the network situation. It reduces collision except first one. Therefore, this protocol saves energy without degrading data delivery ratio. It also increases rate of energy efficiency. From the simulation results obtained, it is clear that IAPCMP has better results than BPCMP, APCMP, and IEEE 802.11 in terms of metrics end-to-end delay and energy efficiency. It also serves the purpose of energy conservation through power control, and decreases collision rate. IAPCMP does not degrade the network quality as generally other protocols do while conserving energy. Therefore, from the simulation results it is shown that IAPCMP yields significant improvement in power saving and delivery ratio of the network.

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